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MONTANA STATE HIGHWAY DEPARTMENT

STATE DOCUMENTS

HIGHWAY PLANNING SURVEY

IN COOPERATION WITH

PUBLIC ROADS ADMINISTRATION

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ENGINEERING-ECONOMIC ANALYSIS
TO ESTABLISH PREFERENCE
IN THE LOCATION OF FEDERAL AID SECONDARY ROUTES
BETWEEN HARLEM AND TURNER AND
HARLEM AND HOGELAND
IN BLAINE COUNTY

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ENGINEERING-ECONOMIC ANALYSIS

TO ESTABLISH PREFERENCE

IN THE LOCATION OF FEDERAL AID SECONDARY ROUTES

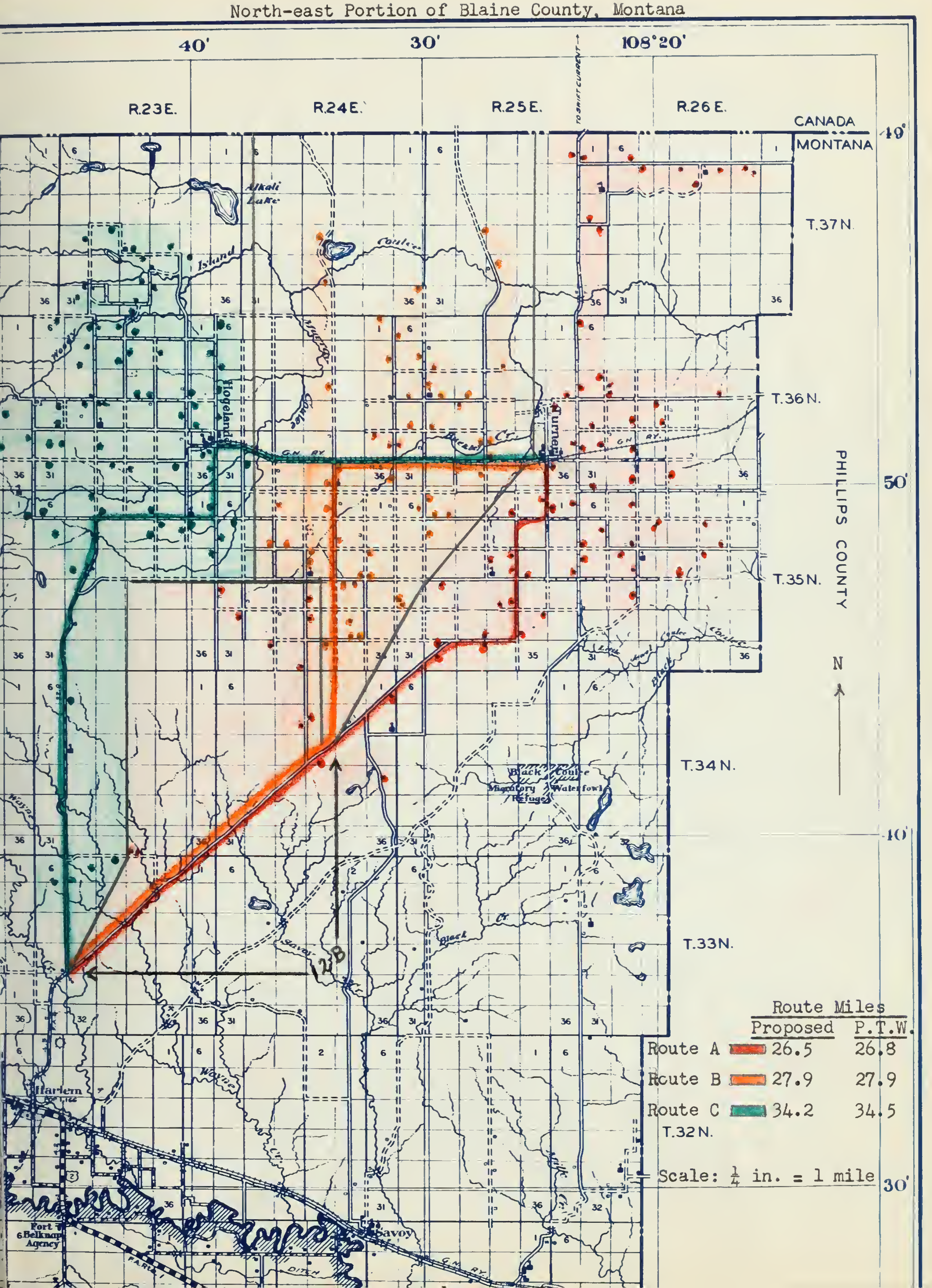
BETWEEN HARLEM AND TURNER AND

HARLEM AND HOGELAND

IN BLAINE COUNTY

September 1946

North-east Portion of Blaine County, Montana



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Montana State Highway Department
Traffic and Planning Section
Public Roads Administration
Basic Design Categories
Table No. 1

Standard	Average Daily Traffic	Classification	Max. Grade	Max. Curvature (Degree)	Sight Distance				Shoulder Width	Width of Road Bed at Grade	Width of Surfacing	Minimum Type of Surfacing	Minimum Base Course
					Non Passing			Passing					
					Horiz. Curvature (Degree)	Vertical Curvature (Algebraic Difference)	Feet	Feet					
0	0-200	20 M 40	7	14	14	SEE TABLE NO. 2.	280	800	3	24	18	Under 1" Oil	5"
1	201-400	50 M 40	7	14	14		290	800	4	28	20	2" Oil	6"
2	401-800	100 M 40	7	14	14		310	1100	5	32	22	2½" Oil	8"
3	801-1800	200 M 40	7	14	14		320	1100	6	34	22	2½" Oil	8"
4	1801-3500	300 M 40	7	14	14		330	1100	8	38	22	2½" Oil	8"
5	0-200	20 M 60	6	6	6		460	1700	3	26	20	Under 1" Oil	5"
6	201-400	50 M 60	6	6	6		460	1700	4	30	22	2" Oil	6"
7	401-800	100 M 60	6	6	6		470	2100	5	32	22	2½" Oil	8"
8	801-1800	200 M 60	6	6	6		480	2100	6	34	22	2½" Oil	8"
9	1801-3500	300 M 60	6	6	6		500	2100	8	38	22	2½" Oil	8"

Note: Roads having over 3500 vehicles per day require special design.

TABLE NO. 2

Table giving length of vertical curve required for various Non - passing sight distances

December 18, 1943

Algebraic Difference between grades for convex curvature.	Length of vertical curve for a Non-passing sight distance of: 280 feet	Length of vertical curve for a Non-passing sight distance of: 290 feet	Length of vertical curve for a Non-passing sight distance of: 310 feet	Length of vertical curve for a Non-passing sight distance of: 320 feet	Length of vertical curve for a Non-passing sight distance of: 330 feet	Length of vertical curve for a Non-passing sight distance of: 460 feet	Length of vertical curve for a Non-passing sight distance of: 470 feet	Length of vertical curve for a Non-passing sight distance of: 480 feet	Length of vertical curve for a Non-passing sight distance of: 500 feet
1.00	96	103	117	125	133	258	269	281	305
2.00	191	205	234	250	266	516	539	562	610
3.00	287	308	352	375	398	774	808	843	915
4.00	382	410	469	500	531	1032	1078	1124	1220
5.00	478	513	586	624	664	1290	1347	1405	1524
6.00	574	615	703	749	797	1548	1616	1686	1829
7.00	669	718	820	874	930	1806	1886	1967	2134
8.00	765	820	938	999	1062	2064	2155	2248	2439
9.00	860	923	1055	1124	1195	2322	2425	2529	2744
10.00	956	1026	1172	1249	1328	2581	2694	2810	3049
11.00	1052	1128	1289	1374	1461	2839	2963	3091	3354
12.00	1147	1231	1406	1499	1594	3097	3233	3372	3659
13.00	1243	1333	1524	1623	1726	3355	3502	3653	3963
14.00	1339	1436	1641	1748	1859	3613	3771	3934	4268

MONTANA HIGHWAY PLANNING SURVEY

GUIDES FOR ESTIMATING 1960 TRAFFIC

			Applies to:
1.	100% =	1941 traffic	
2.	110% = to 125%	Traffic if route is unimproved at present time but expected to be improved by 1960.	F.A., F.A.S. and Class 1, 2, & 3 Forest Highways. Applies to sparcely settled rural areas. (Add extra traffic generated by logging activities on timber utilization roads or other major industries and traffic induced by these activities).
3.	125% = to 150%	Traffic if route is unimproved at present time but expected to be improved by 1960.	F.A., F.A.S. and Class 1, 2, & 3 Forest Highways. Applies in checkerboard well-settled rural areas or on through-roads. (Add extra traffic generated by logging activities on timber utilization roads or other major industries and traffic induced by these activities).
4.	150% = to 200%	Traffic if route is unimproved at present time but expected to be improved by 1960.	F.A., F.A.S. and Class 1,2, & 3 Forest Highways. This applies in exceptional cases such as bottlenecks and natural cutoffs. Some cases, of course, might be much more but these special conditions would require special analysis. (Add extra traffic generated by logging activities on timber utilization roads or other major industries and traffic induced by these activities).

Note: Date of expected improvement does not change traffic estimates for 1960.

130% = expected secular growth 1941 to 1960 -- to be applied to all above conditions except traffic generated by logging activities, or other major industries.

Applies to all roads now constructed. (Without any of above increases)

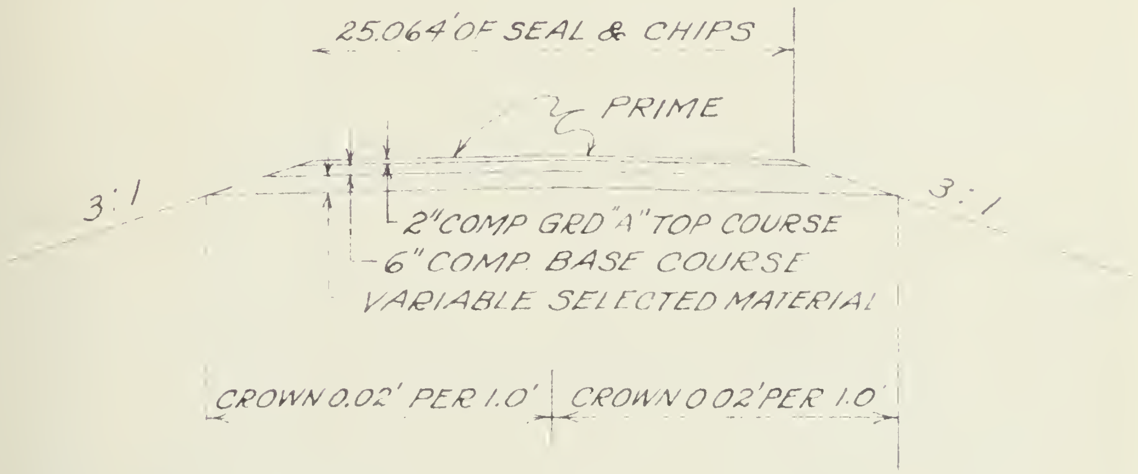
Average summer maximum traffic equals double average ADT except on predominately recreational routes where factor might be as high as 3.

Average summer maximum traffic equals average of several maximum summer days.

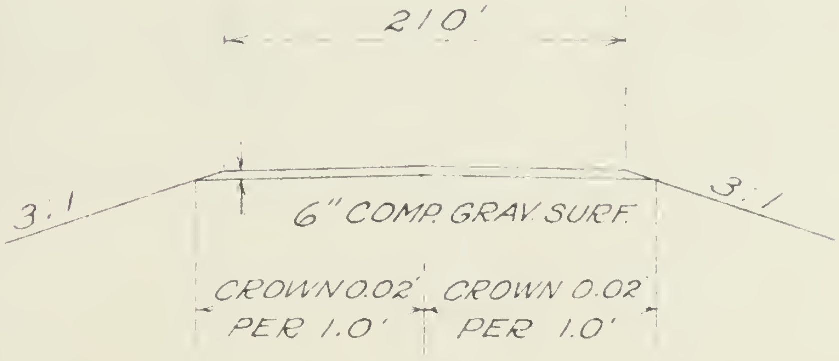
Maximum hour equals 10% of maximum summer ADT. (Usual public traffic), or 15 to 20% on roads used by both the public and by major logging operations or other major industries.

SECONDARY SYSTEM

100 VEHICLES AND LESS THAN 400
AV. 24-HOUR TRAFFIC



UNDER 100 VEHICLES
AV. 24-HOUR TRAFFIC



MONTANA HWY COMM
JUNE 1, 1945

REVISED MAR 25, 1946

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Route A (F.A.S. 241) preferred routing to Turner

Engineering and Economic Analysis
To Establish Preference in the Location
Of Federal Aid Secondary Routes Between
Harlem and Turner and Harlem and
Hogeland in Blaine County

I. SUMMARY OF FINDINGS

The engineering-economic analyses herein developed, indicate that the presently designated F.A.Secondary No. 241 (Route A) should be completed to Turner in preference to the two alternate routes considered.

In recommending the construction of Route A, the residents of Hogeland and vicinity are left without a good road to Harlem, their main trading-Point. It is therefore recommended that the Harlem-Hogeland route be placed upon the Federal Aid Secondary System and improved at some future time when funds are available.

Within the framework of the Oregon Highway Department's Solvency Quotient method, we have set up these analyses, finding that none of the three routes will repay their costs to the state in gasoline tax revenue nor to the road users when the values of benefits are balanced against vehicle operating costs.

However, it is pointed out that these results must be interpreted from the standpoint of the entire state highway system. Were Solvency Quotients the sole criterion then, in Montana, only a few of the main traveled roads would warrant construction. The surplus from income producing roads can, and should, be used for the construction of lesser roads which benefit the system and the people as a whole. Judgement must be exercised as this can be done only so long as the whole remains above the solvency level.

Benefits to the general public, such as better medical, fire protection, police, school, and mail facilities are not an integral part of the analysis but must be taken into consideration.

Summary Table

	Miles	1941 A.D.T.*	1941 Diverted A.D.T.	1960 A.D.T.	Annual Total Cost	Annual Total Income	Annual Total Benefits	**Composite Solvency Quotient
Route A	26.5	48	0	78	$25,621	$4,463	$8,471	0.357
Route B	27.9	41	13	88	$27,831	$5,170	$8,400	0.344
Route C	34.2	42	0	68	$34,203	$4,434	$8,852	0.275

*A.D.T. = Average Daily Traffic (number of vehicles)

**For a complete table of solvency results, see page 19 of this report.

Significance of Solvency Quotient

In relation to Route A, the composite solvency quotient shown in the table above means that as an investment, Route A would return 35.7% of its annual cost every year in combined income from the gasoline tax and benefits to the road users due to their decreased vehicle costs because of use of an improved road.

By the same interpretation, Route B would return 34.4% of its annual cost each year; and Route C would return 27.5% of its annual cost each year.

For a road to be solvent, the composite solvency quotient must equal at least 1.000. This would mean that the annual construction cost of the proposed highway would be just balanced by the annual income from traffic plus the value of mileage savings and time element savings, etc. A quotient in excess of 1.000 indicates that the proposed highway is on the gainful side of the economic ledger and is returning more in valuations that it cost.

II. ROUTE DESCRIPTIONS (see map - frontispiece)

From Harlem to a junction 4.6 miles north of Harlem (and common to all three route analyzed herein) is a gravel, base and surfaced road, constructed as a portion of Federal Aid Secondary No. 241 in 1940.

Route A. That major portion of FAS 241 starting at its junction with FAS 326, which is 4.6 miles north of Harlem, and running 26.8 miles northeasterly to Turner will hereafter, in this report, be designated as Route A.

Route B. From the junction 4.6 miles north of Harlem to a distance of 11.9 miles on FAS 241 construction of a 24 foot roadway with gravel base and six inches of gravel surface, under title of Project 12-B, was undertaken in 1946.

From the northeasterly end-point of this construction northerly approximately nine miles along section lines and over section-line county roads to an intersection with the Hogeland-Turner road and thence easterly for approximately seven miles to Turner, plus 11.9 miles of Project 12-B, gives a total route mileage very close to 27.9, which will hereafter, in this report, be designated as Route B.

Route C. Route begins at the junction 4.6 miles north of Harlem and runs 34.5 miles northerly, easterly and northerly to Hogeland and then easterly to an intersection with FAS 241 at Turner. Hereafter, in this report, this route will be designated as Route C.

Economic and Engineering Conditions

The only towns in this region are Hogeland with a population of 115 and Turner with a population of 227. These two communities could be considered the focii of an irregular ellipse with an east-west length of 25 miles and a north-south width of 13 miles.

The area within this ellipse is practically all under non-irrigated cultivation. Outside this ellipse, the land is almost entirely sub-marginal and used only for grazing. Any other industries in the region are largely dependent on the predominate agricultural economy.

The total population of this area is around 1100, with 800 of them living on 201 farms. Any population increase except anticipated normal secular growth is highly improbable.

A branch line of the Great Northern Railroad terminates at Hogeland and runs east to Turner and on to join the main line at Saco.

The topography of the region is generally rolling terrain. Elevations are as follows: Harlem 2367 feet, Hogeland 3126 feet, and Turner 3042 feet. Water courses are comparatively small and many coulees are dry except during flass-floods and spring run-off. Past glacial action is evident in recessional moraains suitable for gravel surfacing.

The average 12 inches of precipitation per year is about one-half snow. The climate is severe with summer temperatures reaching 100°F. and winter temperatures dropping as low as -50°F. Blizzards and drifting snow are common winter occurances.

III. TRAFFIC

In predicting the economics of this area in 1960, our best assumption is based on traffic trends which show close corelation with economic trends. Available data shows this area to be a relatively stable one in regard to traffic. There is nothing observable in the economic picture of the region to indicate more than average growth from the present to 1960.

The three routes analyzed, besides serving neighborhood traffic, are feeder roads to and from Harlem which is on F.A.Primary No.2, and between Hogeland and Turner. Traffic is concentrated on a triangle whose corners are Harlem, Hogeland, and Turner. As the 1960 Average Daily Traffic for these routes does not exceed 100 when expanded from 1941, it is assumed that any highway construction undertaken would be similar to the gravel base, 24 foot roadway and 6 inch gravel surface now being built as a standard for Project 12-B.

There has been little change in total volume of traffic since Planning Survey counts were first made in 1936. Even during the war years, there was never more than 6% decline in the total number of vehicles counted from an average pre-war year. This stability of traffic indicates a maximum of business and necessity driving and a minimum of pleasure and tourist travel. Origin-destination studies show a very low percentage of foreign passenger cars, and vehicle ownership outside Blaine County.

The railway, paralleling the road from Hogeland to Turner, makes long distance heavy trucking of farm produce into Harlem unnecessary. Long Distance heavy trucking of supplies from Harlem to Hogeland or Turner is also unnecessary. Counts of vehicles by types show a very low percentage of heavy trucks. The proportion of light trucks to passenger cars is such that we anticipate no higher ratio in 1960 than at present.

Traffic Diversion

A study of travel distances derived from the actual county road and farm locations gave the number of residents that might find it advantageous to divert their traffic from the route they now use to another that might be improved, with the increased travel distances involved. The results are briefly presented in the following paragraphs.

Residents of Turner and 130 farms find their shortest travel distance to Harlem on Route A. The residents of five farms, by driving one to two miles farther, could use portions of Route C and roads leading to it. Residents of Turner and the remaining 125 farms would have to drive three to 14 miles farther to use these alternate roads.

Residents of Hogeland and 71 farms find their shortest travel distance to Harlem on Route C. The residents of Hogeland and ten farms, by driving two to three miles farther, could use portions of Route A and roads leading to it. Residents of the remaining 61 farms would have to drive four to nine miles to use these alternate roads.

Therefore, as the road situation now exists, with Routes A and C the best available roads to and from Harlem very few residents would find it advantageous to travel an alternate route unless there was decided superiority in the travel-conditions of the alternate route.

Traffic Diversion (cont'd)

However, the construction of Route B would, besides directly serving a definite area, tend to divert traffic from other areas now served by Routes A and C.

Residents of 55 farms would find their shortest travel distance to Harlem on Route B. An estimated 50% of the residents of Hogeland (pop.115)and ten farms might divert their traffic to Route B, and an estimated 75% of the residents of Turner (pop.227) and 27 farms northeast of Turner might also divert their traffic to Route B.

Assuming the above estimates to represent a reasonable traffic diversion, we have 220 rural residents who would find their shortest travel distance to Harlem via Route B and an additional 316 rural and 228 urban residents who could be expected to drive an average of 1.3 additional miles to gain the advantages of Route B.

The above population data is based on the 1940 census and a report by M.J. Wilcomb (Highway Engineer, Public Roads Administration) of October 23, 1939, in which the rural population of this area is given as 800. Our count of the 1936 Highway Planning Survey map shows 201 farms thus giving an average of four residents per farm. From 1930 census data, we glean the following data: In Montana there was an average of 3.92 persons per private family, 4.07 persons per private dwelling and 3.42 persons was the median for rural farm families. Therefore, four persons per farm corresponds with Montana averages quite closely.

As a means of arriving at the expected average daily traffic for Route B, we have resorted to proportioning traffic to this route in the same ratio as the population has created traffic on Routes A and C derived from the traffic profiles of 1941, as follows:

(1) For the year 1941, the 1146 residents served by Routes A and C created an A.D.T. of 81.2 vehicles. At this ratio 251 residents would create an A.D.T. of 17.8 vehicles. These 251 persons represent the 75% of the Turner plus 27 farm population that would enter Route C at Turner and swell the existing A.D.T. on the Turner-Hogeland road by 17.8 vehicles.

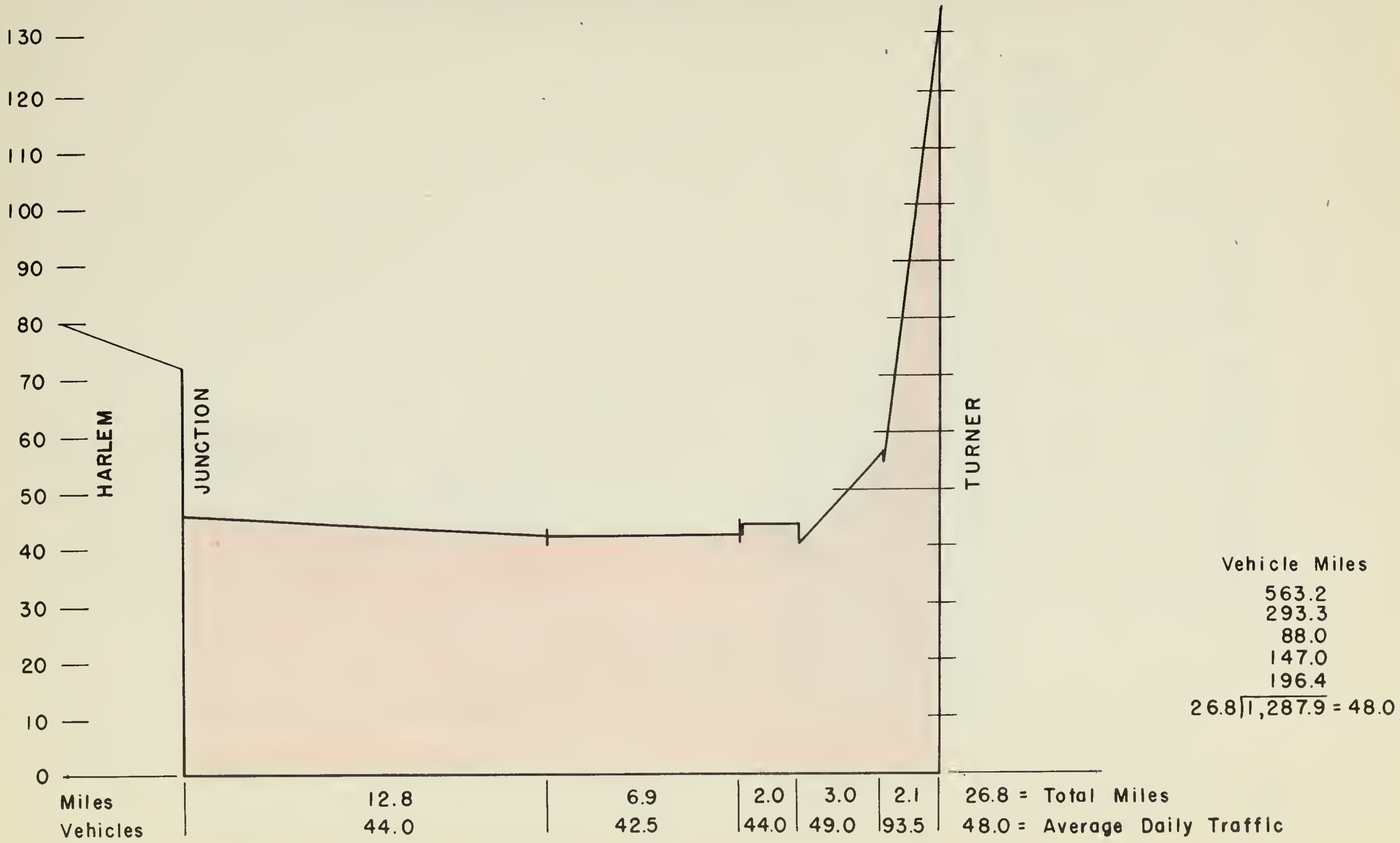
(2) Using the same procedure as above, we find the 104 residents of the 26 farms north of the Turner-Hogeland road contributing an additional A.D.T. of 7.4 vehicles.

(3) Again, as above, we find the 67 persons (representing 50% of the population of Hogeland and five farms north of Hogeland) contributing an additional A.D.T. of 4.8 vehicles at the intersection of Route B with Route C, 4.4 miles east of Hogeland.

(4) Once more, as above, we find 116 persons from 29 farms contributing an A.D.T. of 8.2 vehicles to the nine miles of Route B running directly north and south.

(5) We must now create a traffic profile from the above data in order to get the A.D.T. for the entire route. This graphical procedure was carried out resulting in an A.D.T. of 54.4 vehicles for the entire 27.9 miles of Route B. See page 6.

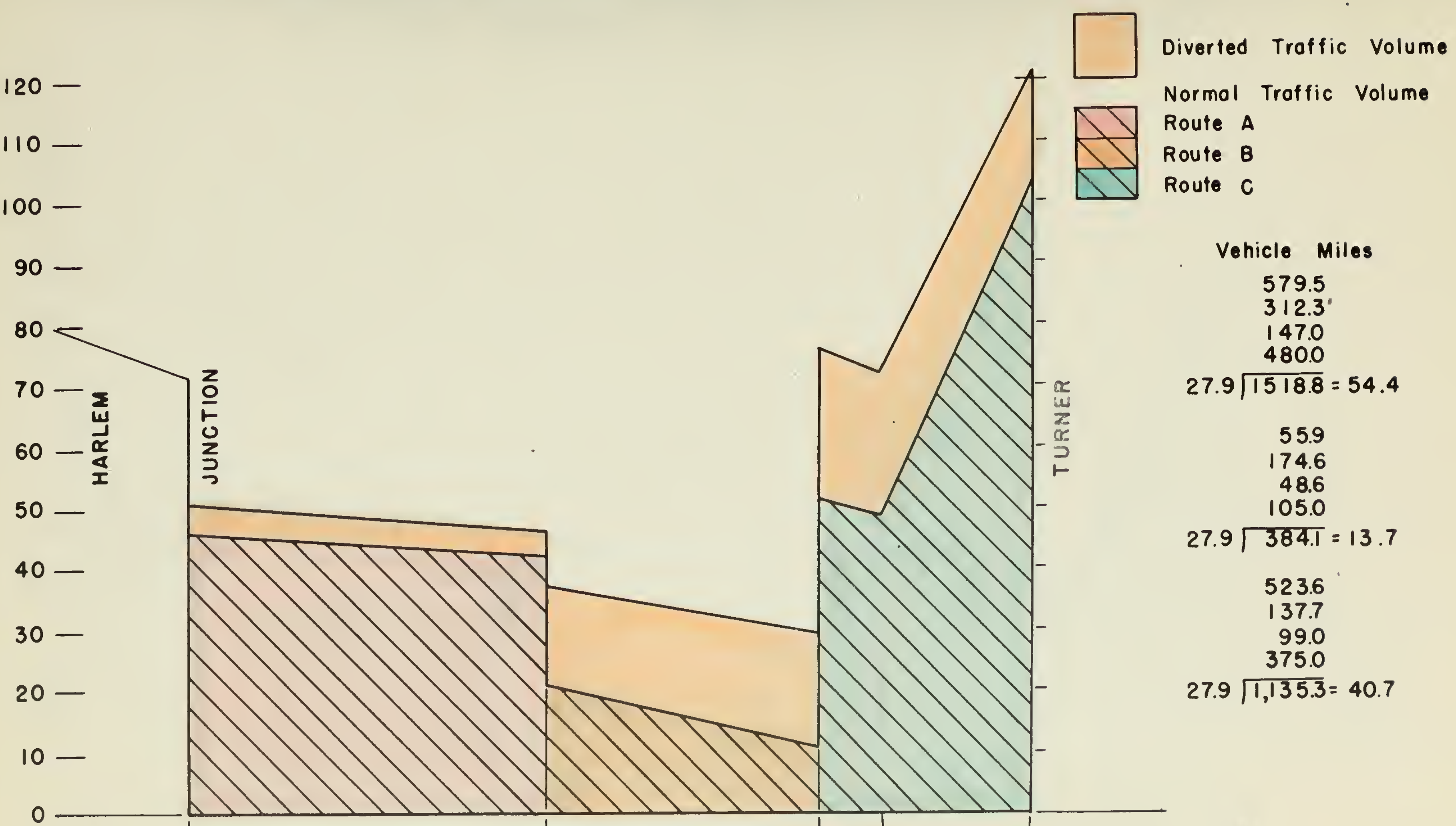
1941 TRAFFIC VOLUME PROFILE FOR ROUTE A
BLAINE COUNTY, MONTANA, SEPT. 1946



Vehicle Miles

563.2
293.3
88.0
147.0
196.4
26.8)1,287.9 = 48.0

1941 TRAFFIC VOLUME PROFILE FOR ROUTE B
BLAINE COUNTY, MONTANA, SEPT. 1946



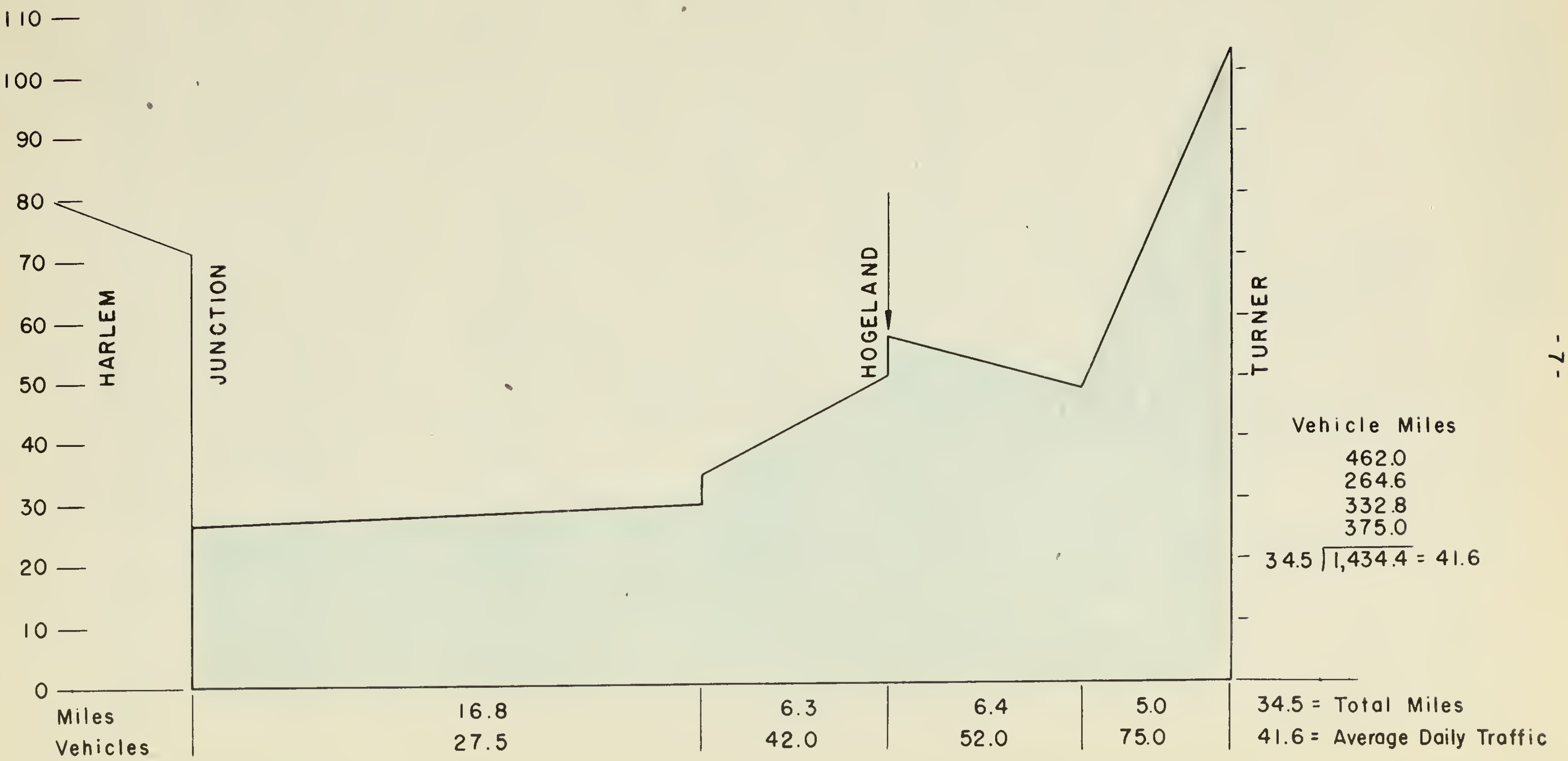
Vehicle Miles
579.5
312.3
147.0
480.0
27.9 ⟌1518.8 = 54.4

55.9
174.6
48.6
105.0
27.9 ⟌384.1 = 13.7

523.6
137.7
99.0
375.0
27.9 ⟌1,135.3 = 40.7

Miles		11.9	9.0	2.0	5.0	27.9 = Total Miles
Vehicles	Total	48.7	34.7	73.8	96.0	54.4 = Average Daily Traffic
	Diverted	4.7	19.4	24.5	21.0	13.7 = Average Daily Traffic
	Normal	44.0	15.3	49.5	75.0	40.7 = Average Daily Traffic

1941 TRAFFIC VOLUME PROFILE FOR ROUTE C
BLAINE COUNTY, MONTANA, SEPT. 1946



IV. ECONOMIC ANALYSIS

A. ANNUAL COST CALCULATIONS

Routes A, B, and C, Blaine Co., Montana, September 1946

	Average Cost per Mile			
	Basis (1) 12-B	Route A	Route B	Route C
1. Grading & Clearing	$ 4,651	$ 4,623	$ 4,622	$ 4,600
2. Gravel Base and Surfaces	4,339	4,373	4,374	4,400
3. Major Drainage Structures	2,793	1,254	1,668	1,681
4. Minor Drainage Structures	1,081	1,036	1,035	1,000
5. Rights of Way	76	144	147	200
6. Engineering and Administration Costs				
a. Grading and Gravel	800	800	800	800
b. 5% of Cost of Major Drainage	140	63	83	84
Subtotal	13,880	12,293	12,729	12,765
Plus 10% for contingencies	1,388	1,229	1,273	1,277
TOTAL AVERAGE COST PER MILE	$15,268	$13,522	$14,002	$14,042

Total cost for Project Miles..........	26.5 mi.	27.9 mi.	34.2 mi.
1. Grading and Clearing	$122,504	$128,944	$157,320
2. Gravel Base and Surface	115,879	122,039	150,480
3. Major Drainage Structures @$100/lin. ft.	33,242	46,542	57,500
4. Minor Drainage Structures	27,467	28,867	34,200
5. Rights of Way	3,824	4,104	6,840
*6. Engineering and Administration Costs			
a. Grade and Gravel	21,200	22,320	27,360
b. 5% of Cost of Major Drainage	1,662	2,327	2,875
Subtotal	325,778	355,143	436,575
Plus 10% for Contingencies	32,578	35,514	43,658
TOTAL UNAMORITIZED COST OF CONSTRUCTION	358,356	390,657	480,233
TOTAL ANNUAL CAPITAL COST ** (20 years @ 2½%)	22,971	25,041	30,783
***Maintenance Cost @ $100 per mile	2,650	2,790	3,420
TOTAL ANNUAL COSTS	$25,621	$27,831	$34,203

(1) Project 12-B (11.9 miles) was constructed in 1946 and is common to both Routes A and B. Construction costs of 12-B have been used as a basis for estimating costs for entire Routes of A, B, and C. Timber trestles on 12-B averaged $100 per lineal foot.

* These Engineering and Administrations costs based on similar project costs experienced in the past.

** All construction costs estimates herein have been assigned an interest rate of 2½% to be amortized in 20 years. This time period is deemed significant of the service life of the proposed improvement. It is believed that traffic will require roads of higher standards as time goes on and thus require a greater outlay on reconstruction. Therefore, the road "as built" should lay up a reserve to meet probable increased construction costs in the future.

*** From consideration of various statistics ascertained in the course of the Highway Planning Survey, we have assigned a maintenance cost of $100 per mile per year.

B. AVERAGE DAILY TRAFFIC

Routes A, B, and C, Blaine Co., Montana September 1946

	1941 A.D.T.	Plus 25% on compl. of const.	Plus 30% 1960 A.D.T.
Route A			
Passenger cars - Montana	31	39	50
Trucks, light	17	21	28
Total	48	60	78

	1941 A.D.T.	Plus 25% on compl. of const.	Plus 30% 1960 A.D.T.
Route B			
Normal Traffic			
Passenger cars - Montana	27	34	44
Trucks, light	14	18	23
Total Normal Traffic	41	52	67
Diverted Traffic			
Passenger cars - Montana	8	10	13
Trucks, light	5	6	8
Total Diverted Traffic	13	16	21
Total Traffic	54	68	88

	1941 A.D.T.	Plus 25% on compl. of const.	Plus 30% 1960 A.D.T.
Route C			
Passenger cars - Montana	31	38	50
Trucks, light	11	13	18
Total	42	51	68

Notes and Comments

1941 A.D.T. derived from 1941 Traffic Profiles for Routes A and C.
1941 A.D.T. for Route B derived from Traffic Profile created from estimates of normal and diverted traffic based on population-traffic ratio.

The 25% increase on completion of construction is based on "Guides for Estimating 1960 Traffic" (see p. iii Prefatory Assembly). While region may be considered as well-settled, it is not on through-roads. Relative stability of area and present fair condition of roads lend support to the choice of 25% as an adequate increase.
The 30% increase to 1960 exnands the traffic according to the normal growth rate based on normal increase in population and vehicle ownership.

Lacking sufficient suitable vehicle classification data, vehicle proportions were modified within limits derived from a study of automatic counter data for similar secondary roads.
Heavy truck and foreign passenger car A.D.T. was less than 0.5 vehicles when expanded to 1960 on any of the three routes, so was therefore included within the classification shown.

C. ANNUAL REVENUE

Routes A, B, and C, Blaine County, Montana, September 1946

Traffic Type	A.D.T. Vehicles	Average Annual Vehicles	Avg. Gross tons per Vehicle	Average Annual Gross Tons	Miles	Average Annual Ton-Miles	Unit net Revenues per Ton-Mile	Total Annual Net Revenues
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ROUTE A								
Passenger cars - Mont.	50	18,250	1.50	27,375	26.5	725,437	0.002188	$1,587
Trucks, light	28	10,220	3.27	33,419	26.5	855,604	0.003248	2,876
Total, all vehicles	78	28,470		60,794	26.5	1,611,041		$4,463
ROUTE B (Normal)								
Passenger cars - Mont.	44	16,060	1.50	24,090	27.9	672,111	0.002188	$1,471
Trucks, light	23	8,395	3.27	27,452	27.9	765,910	0.003248	2,488
Total, all vehicles	67	24,455		51,542	27.9	1,438,021		$3,959
ROUTE B (Diverted traffic)								
Passenger cars - Mont.	13	4,745	1.50	7,118	26.0	185,068	0.002188	$ 405
Trucks, light	8	2,920	3.27	9,548	26.0	248,248	0.003248	806
Total, all vehicles	21	7,665		16,666	26.0	433,316		$1,211
ROUTE C								
Passenger cars - Mont.	50	18,250	1.50	27,375	34.2	936,225	0.002188	$2,048
Trucks, light	18	6,570	3.27	21,484	34.2	734,753	0.003248	2,386
Total, all vehicles	68	24,820		48,859	34.2	1,670,978		$4,434

Col.

1. Average Daily Traffic for 1960 as developed in Table on page 9.
2. A. D. T. of Col. 1 multiplied by 365, the number of days in the year.
3. Avg. Gross ton figures for each class of vehicle were ascertained during course of research work by Planning Survey.
4. Avg. Annual Vehicles of Col. 2 multiplied by Avg. Gross Tons per Vehicle of Col. 3.
5. Length in miles of the proposed routes, or for Route B diverted traffic, average no. of miles traveled by diverted traffic: minus 1.3 mi. of extra travel, income from which must be subtracted from total income produced.
6. Avg. Annual Gross Tons of Col. 4 multiplied by Miles of Col. 5.
7. Income accrues by virtue of the Gasoline License Tax Levy. Unit net Revenues rates were derived from a general study conducted by the Planning Survey.

MILEAGE ELEMENT SAVINGS

Routes A and C, Blaine Co., Montana, September 1946

	Route A New	Route A Existing	Route C New	Route C Existing
*1. Distance				
Length (miles)	26.5	26.8	34.2	34.5
Distance saving (miles)	0.3		0.3	
Average annual traffic (tons)	60,794		48,859	
Annual traffic saving (ton-mi.)	18,238		14,658	
Cost ($/ton-mile)	0.01984		0.02006	
Total Annual Saving	$362		$294	
*2. Surface				
Roadway surface type	Gravel	Earth	Gravel	Earth
Roadway surface type coefficient	0.19	0.28	0.19	0.28
Saving coefficient	0.09		0.09	
Avg. annual traffic (ton-mi.)	1,611,041		1,670,978	
Saving ($/ton-mile)	0.001786		0.001806	
Total Annual saving	$2,877		$3,018	
*3. Rise and Fall				
Rise and fall (feet)	968	1,275	1,363	2,076
Saving (feet)	307		713	
Saving (foot-tons)	18,663,758		34,836,467	
Saving ($/foot-ton)	$2,693 \times 10^{-6}$		$2,863 \times 10^{-6}$	
Total annual saving	$50		$100	
*4. Alignment				
Curvature rating	6	0	6	0
Points improvement	6		6	
Saving (point-ton-miles)	9,666,246		10,025,868	
Saving ($/point-ton-mile)	0.0001		0.0001	
Total annual saving	$967		$1,003	
TOTAL ANNUAL MILEAGE ELEMENT SAVINGS	$4,256		$4,415	

Mileage Element Savings accrue to traffic as a result of decreased travel distance, rise and fall, and gradient, and also as result of improved riding surface and alignment. Change in gradient was negligible on all three routes. All Mileage Element Factors tend to decrease wear and tear on engines and tires and increase the miles per gallon of fuel consumed.

*1, *2, *3, *4, see Details of Development on page 13.

Route B (normal and diverted traffic), Blaine Co., Montana, September 1946

	Route B (Normal)		Route B (Diverted)	
	New	Existing	New	P.T.W.
***1. Distance**				
Length in miles	27.9	27.9	27.3(avg)*	26.0(avg)*
Distance saving (miles)	0		-1.3	
Average annual traffic (tons)	51,542		16,666	
Annual traffic saving (ton-mi.)	0		21,666	
Cost ($/ton-mile)	0.01984		0.01984	
Total Annual Saving	0		-$430	
***2. Surface**				
Roadway surface type	Gravel	Earth	Gravel	Earth
Roadway surface type coefficient	0.19	0.28	0.19	0.28
Saving coefficient	0.09		0.09	
Avg. annual traffic (ton-mi.)	1,438,021		454,982	-21,660
Saving ($/ton-mile)	0.001786		0.001786	0.01984
Total Annual Saving	$2,568		$813	-$430 = $383 Net Gain
***3. Rise and Fall**				
Rise and fall (feet)	936	1,178	936	1,178
Saving (feet)	242		242	
Saving (foot-tons)	12,473,164		4,033,172	
Saving ($/foot-ton)	2,693 x 10^{-6}		2,693 x 10^{-6}	
Total Annual Saving	$34		$11	
***4. Alignment**				
Curvature rating	7	0	7	0
Points improvement	7		7	
Saving (point-ton-mile)	10,066,147		3,184,874	
Saving ($/point-ton-mile)	0.0001		0.0001	
Total Annual Saving	$1,007		$318	
TOTAL ANNUAL MILEAGE ELEMENT SAVINGS	$3,609			$282 total net gain

*Average miles traveled by diverted traffic: See Traffic Diversion page 3 for source of A. D. T.
A. D. T. of 4.6 vehicles have Present Traveled Way of 23.1 miles and New Travel Way of 25.3 miles.
A. D. T. of 17.4 vehicles have Present Traveled Way of 26.8 miles and New Travel Way of 27.9 miles.
Therefore, all vehicles have Present Traveled Way of 26.0 miles and New Travel Way of 27.3 miles.
Therefore, by weighted average, diverted traffic will travel 1.3 miles farther to use proposed improved road.
*1, *2, *3, *4. see Details of Development on following page.

E. MILEAGE ELEMENT SAVINGS

Details of Development

1. Distance: Source of cost in dollars per ton-mile.

Distance saved cuts down the over-all vehicle operating costs. Oregon Highway Bulletin 7 on page 274 has developed from operating cost per ton-mile, graphs which allow one to determine a composite ton-mile cost in the following manner (using Route A as an example).

By reference to column 3 of C. Annual Revenues, we find opposite Trucks, light, under Route A, that 3.27 tons is the average gross tons per vehicle.

$$\frac{\text{Average Daily Traffic (trucks)}}{\text{Average Daily Traffic (all vehicles)}} = \frac{27}{77} = 35.0\% \text{ percent of truck traffic}$$

Be reference to figs. 113 and 114 of the Oregon Bulletin, it is found that the average cost per ton-mile of traffic in the proportions and weights given above would be $0.01984.

In the particular case of Route B, distance is not saved, but diverted traffic must travel 1.3 miles farther (on the average) in order to use Route B. Therefore, the cost of operating a vehicle over this additional mileage is a loss instead of a savings and we have so computed it at the same value per ton-mile as would have been saved if the distance had been shortened.

2. Surface: Source of Roadway Surface Type Coefficient

From page 278 and 288 of Oregon Bulletin 7, we copy the following table of coefficients Oregon has developed as a basis for evaluating roadways in relation to type of surface:

Unimproved earth	0.28
Loose gravel and crushed rock	0.19
Oiled surface (light treatment)	0.03
Bituminous and Portland cement concrete pavement	0.00

Savings in dollars per ton-mile

The cost in dollars per ton-mile as determined for distance saving, as above, when multiplied by the saving coefficient result in Savings in dollars per ton-mile.

In the particular case of Route B, diverted traffic has to travel 1.3 additional miles (on the average) before gaining the benefits of the improved surface of Route B. Therefore, for this distance of 1.3 miles, we have computed a loss to the motorist instead of a saving. The same principles of development were used as in computing a saving.

3. Rise and Fall: Source of Rise and Fall feet

From a suitable elevations as controls and estimates made from profile maps, we arrive at the number of feet of rise and fall for each route.

Savings in dollars per foot-tons

Using Route A for example: As in Distance Savings (above), we have 3.27 as the average gross tons per vehicle. The average grade for Route A was determined as approximately 0.5%. Using these two factors, we determine from the graph of Fig. 123, p. 297 of Oregon Bulletin 7, that the Truck Fuel Cost for one foot Rise and Falls is $\$0.50 \times 10^{-6}$. Combining this with

E. MILEAGE ELEMENT SAVINGS (cont'd)

the value for passenger cars given as $\$3.72 \times 10^{-6}$, and in the ratio of 35% of trucks (see under Distance above) as follows:

$$\begin{array}{rcl} .35 \times 0.50 \times 10^{-6} & = & 0.175 \times 10^{-6} \\ .65 \times 0.72 \times 10^{-6} & = & 2.418 \times 10^{-6} \\ \hline \end{array}$$

We get..............combined cost.. = 2.693×10^{-6} dollars per foot-ton rise and fall.

4. Alignment: Source of Curvature Rating

Curvature rating is based on a ten point scale considering 0 as a very poor curvature rating and ten as a very high standard of curvature. This system is adapted from Oregon Bulletin 7, page 302-305.

Savings in dollars per point-ton-mile has been derived by Oregon (see Bulletin page 304) as $0.0001 per point-ton-mile.

In addition to the improvement in alignment of Routes A, B, and C, the proposed standard will improve the sight distances and superelevations. Thus, we consider a six point improvement for Route A and C and a seven point improvement for Route B to be on the conservative side.

E. TIME ELEMENT SAVINGS

Routes A, B, and C, Blaine Co., Montana, September 1946

	Route A		Route B (3)		Route C	
	New	Existing	New	Existing	New	Existing
Annual Traffic Volume						
Private Passenger Cars (per year)	18,250		20,075		18,250	
Trucks, light (per year)	10,220		10,585		6,570	
Totals	28,470		30,660		24,820	
Private Passenger Cars						
Average speed (miles per hour) (1)	38	30	38	30	38	30
Distance (miles)	26.5	26.8	27.9	27.6	34.2	34.5
Time (hours per trip)	0.6974	0.8933	0.7342	0.9200	0.9000	1.1500
Time savings per vehicle	0.1959		0.1858		0.2500	
Value of savings ($/vehicle-hour) (2)	$0.60		$0.60		$0.60	
Annual traffic volume	18,250		20,805		18,250	
Total value of time savings.	$2,145		$2,319		$2,738	
Trucks, light						
Average speed, (miles per hour) (1)	35	27	35	27	35	27
Distance (miles)	26.5	26.8	27.9	27.6	34.2	34.5
Time (hours per trip)	0.7571	0.9926	0.7971	1.0222	0.9771	1.2778
Time savings per vehicle	0.2355		0.2251		0.3007	
Value of savings ($/vehicle-hour) (2)	$0.86		$0.86		$0.86	
Annual traffic volume	10,220		11,315		6,570	
Total value of time savings.	$2,070		$2,190		$1,699	
TOTAL ANNUAL TIME ELEMENT SAVINGS	$4,215		$4,509		$4,437	

Time Element Savings accrue to traffic as a result of the same factors that result in Mileage Element Savings, i.e. decreased travel distance, rise, and fall, and gradient, and improved riding surface, and alignment. These factors allow greater speed of travel.

(1) The average speeds used in the above table were based on data published in Oregon Technical Bulletin No. 7, P. 320.

(2) The values of savings ($ per vehicle-hour) were based on data published in Oregon Technical Bulletin No. 7, P. 322.

(3) Time Savings developed for Route B Total Traffic only. 100% of time element savings are classed as non-fuel function and therefore, do not appear in the derivation of K_2; see p. 16, 17, and 18 of this report. Distance of 27.6 miles is weighted average miles traveled by normal plus diverted traffic.

F. TRAFFIC BENEFITS

Route A, B, and C, Blaine County, Montana, September, 1946

	Route A		Route B		Route B Diverted Traffic		Route C	
Mileage Element Factors	Fuel Function	Non-Fuel Function	Fuel Function	Non-Fuel Function	Fuel Function	Non-Fuel Function	Fuel Function	Non-Fuel Function
Distance savings	$ 138	$ 224	$ 0	$ 0	$ -163	$ -267	$ 112	$ 182
Roadway surface savings	1,381	1,496	1,233	1,335	184	199	1,449	1,569
Rise and fall savings	50		34		11		100	
Alignment savings	483		503	504	159	159	501	502
Total mileage savings	$2,052	$2,204	$1,770	$1,839	$ 191	91	$2,162	$2,253
Time Element Factors								
Total Time Savings		$4,215		$4,509				$4,437
Total Fuel Function Benefits	$2,027		$1,770		$ 191		$2,162	
Total Non-Fuel Function Benefits		$6,419		$6,348		$ 91		$6,690

Traffic Benefits: The above tabulation allocates Mileage Element Savings and Time Element Savings to a Fuel and Non-Fuel Function basis in accordance with proportions developed in the Oregon Technical Bulletin No. 7 p. 327 as follows:

Mileage Element Factors	Fuel Function	Non-Fuel Function
Distance savings	38%	62%
Roadway surface savings-		
Earth to gravel	48%	52%
Rise and Fall	100%	0%
Alignment savings	50%	50%
Time Element Factors	0%	100%

G. DERIVATION OF QUOTIENTS

Route A, Blaine Co., Montana, September 1946

Income, average annual . . . . $I_{ar} = \$4,463$

Cost, average annual . . . . $C_a = \$25,621$

Benefits, non-fuel . . . . $B_n = \$6,419$

Benefits, fuel . . . . $B_f = \$2,052$

$K_1 = 1.00$

$K_2 = 0$

$K_3 = 0.05/0.20 = 0.25$

$K_1C_a = \$25,621$

Solvency Quotient. . . . . $Q_s = I_{ar}/K_1C_a = \$4,463/25,621 = 0.1742$

Non-fuel Benefit Quotient. . . . . $Q_{Bn} = B_n/K_1C_a = 6,419/25,621 = 0.2505$

Fuel Benefit Quotient. . . . . $Q_{Bf} = B_f/K_1C_a = 2,052/25,621 = 0.0801$

Composit Solvency Quotient . . . . $Q_c = 0.707\ (Q_s + Q_{Bn} + Q_{Bf}) = 0.3569$

Route B, Blaine Co., Montana, September 1946

Income, average annual . . . . $I_{ar} = \$5,170$

Cost, average annual . . . . $C_a = \$27,831$

Benefits, non-fuel . . . . $B_n = \$6,439$

Benefits, fuel . . . . $B_f = \$1,961$

$K_1 = 1.00$

$K_2 = 191/1961 = 0.097$

$K_3 = 0.05/0.20 = 0.25$

$K_2K_3 = 0.024$

$1-K_2K_3 = 0.976$

$K_1C_a = \$27,831$

Solvency Quotient. . . . . $Q_s = 5,170/27,831 = 0.1858$

Non-fuel Benefit Quotient. . . . . $Q_{Bn} = 6,439/27,831 = 0.2314$

Fuel Benefit Quotient. . . . . $Q_{Bf} = 1,961/27,831 = 0.0705$

Solvency Quotient. . . . . $Q'_s = Q_s-K_2K_3Q_{Bf} = 0.1858-0.0017 = 0.1841$
(corrected for diverted traffic)

Composite Solvency Quotient. . . . . . . $Q_c = 0.707\ (Q_s + Q_{Bn}/Q_{Bf}(1-K_2K_3))$

$Q_c = 0.707 \times 0.4860 = 0.3436$

Notes with explanation of constants and comments on Quotients will be found on page 18 following Derivations.

G. DERIVATION OF QUOTIENTS
Route C, Blaine Co., Montana, September 1946

Income, average annual . . . . $I_{ar} = \$4,434$ $K_1 = 1.00$

Cost, average annual . . . . $C_a = \$34,203$ $K_2 = 0$

Benefits, non-fuel . . . . $B_n = \$6,690$ $K_3 = 0.05/0.20 = 0.25$

Benefits, fuel . . . . $B_f = \$2,162$

$K_1C_a = \$34,203$

Solvency Quotient. . . . . $Q_s = I_{ar}/K_1C_a = 4,434/34,203 = 0.1296$

Non-fuel Benefit Quotient. . . . . $Q_{Bn} = B_n/K_1C_a = 6,690/34,203 = 0.1956$

Fuel Benefit Quotient. . . . . $Q_{Bf} = B_f/K_1C_a = 2,162/34,203 = 0.0632$

Composite Solvency Quotient. . . . . . . $Q_c = 0.707\ (Q_s + Q_{Bn} + Q_{Bf}) = 0.2746$

Notes on Constants and Quotients

K_1 - - The constant K_1 represents the pro rata cost chargeable to road user funds, the gasoline license tax levy in this case.

K_2 - - The constant K_2 represents the proportion of the total fuel savings which derives from the diverted traffic. Route B having the only appreciable diverted traffic has had its fuel savings computed separately to give a total of \$191 for the diverted traffic and \$1,961 for total traffic. This results in a factor of 0.097 as K_2 for Route B.

K_3 - - The constant K_3 represents the ratio of fuel tax to the total fuel cost.

K_2K_3 - By combining the constant K_2K_3 we arrive at a measure of percentage factor showing the relative decrease in revenues on adjoining highway systems which occurs by reason of diverting traffic to the new routing.

Q_s - - Q_s represents the solvency quotient. If it were 1.00, annual revenues would balance estimated annual expenditures. When the quotient is less than 1.0 as in these cases, estimated revenues do not equal estimated expenditures.

Q'_s- - Q'_s is a corrected solvency quotient representing the net solvency of the proposed improvement in respect to other parts of the highway system.

Q_c - - Q_c represents the Composite Solvency Quotient. The solvency quotient showed the ratio between costs and revenues. In the composite quotient the value of benefits have been added in along with the revenues to give a new ratio more inclusive in determining the projects true value to the state highway system as a whole. When the quotient is less than 1.00, as in these cases, estimated revenues and benefits do not equal estimated expenditures.

SUMMARY TABLE OF SOLVENCY RESULTS

Quotient Descriptions	Route Designation		
	A	B	C
Q_s = Annual Revenues ÷ Annual Capital Costs	0.174		0.130
Q_{Bn} = Annual Non-fuel Benefits ÷ Annual Capital Costs	0.251	0.231	0.196
Q_{Bf} = Annual Fuel Benefits ÷ Annual Capital Costs	0.080	0.071	0.063
Q'_s = Solvency quotient corrected for diverted traffic		0.184	
Q_c = Composite Solvency	0.357	0.344	0.275

V. RECOMMENDATION

The Oregon State Highway Department has attempted to reduce to a dollars and cents valuation, the many various factors that, balanced against each other, make the construction of a road feasible or unfeasible. They have further combined these valuations in such a manner as to arrive at one final figure which serves both as an index for comparison of various routes and also as a criterion of the value of each road to the communities served by it and to the state.

It is impossible for any one man to "carry in his head" a proper consideration of the relative values for all these factors and arrive at precise standards of comparability for the large number of roads to be rated. Nor would any two men, however reliable their judgement, arrive at identical comparisons for a large number of projects.

Therefore, this reasonable method of applying engineering and economic principles that reduce the wide variations in personal judgement to a more standard practice resulting in a good index for comparison and valuation, serves a useful purpose.

So in accordance with the Oregon Highway Department's method, we have developed the mathematical relationships between estimated costs and possible future revenues and benefits, with final results as shown in the Summary Table of Solvency Results, above.

By way of interpretation, Route A will return 17% of its cost in gasoline tax revenue. When the value to the road users of increased vehicle life and decreased vehicle operating costs and travel time (due to decreased travel distance, rise and fall; better road surface, and alignment, etc.) is added, the percentage of cost that may be repaid is raised to 35.7%. As stated previously on page 1, it is expected that the income producing roads should have their profits used for the construction of lesser income producing roads as long as the entire highway system remains solvent. Other factors of necessity and convenience justify road construction in this area regardless of tax-burden assumed.

Therefore, in conclusion, we state that when construction is continued to Turner, Route A should be the preferred routing, and to supply Hogeland and vicinity with an outlet, the Harlem-Hogeland road should be included in the Federal Aid Secondary System.

In support of this conclusion, attention is called to the fact that it is almost mandatory, due to the fact that Route A has already been constructed to a point 16.5 miles north-east of Harlem, that either Route A or B be selected and as shown previously, Route A is to be preferred.

This, of course, leaves the important Hogeland area with its 100 places of residence and an estimated traffic for 1960 of 51 vehicles to and from Harlem, without an improved road. Consequently, in as much as the county has requested this section be placed on the system, we believe the analysis herein outlined justifies its inclusion thereon.

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